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Field and cluster RR Lyrae stars as stellar tracers

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Abstract. We present an overview on pulsation properties of RR Lyrae stars in the Galaxy and in Local Group dwarf galaxies. We discuss the key information that RR Lyrae might provide on their parent population, and in particular on their metallicity distribution.

Key words. Galaxy: stellar content – Local Group – Stars: oscillations – Stars: variables: other

1. Introduction

The large photometric databases collected by microlensing projects (EROS, MACHO, OGLE, PLANET) substantially increased the number of variable stars for which are available accurate estimates of pulsation properties. This provided the unique opportunity to investigate in detail the occurrence of peculiar phenomena such as Bump and Beat Cepheids, Blazhko RR Lyrae, and mixed-mode variables. Even though their existence was predicted long time ago, second overtone Cepheids have also been recently discovered in the Small Magellanic Cloud (SMC) (Udalski et al. 1999). On the basis of a sample of 7900 field RR Lyrae stars observed in the bar of the Large Magellanic Cloud (LMC), Alcock et al. (1996) also suggested the identification of second overtone pulsators. This finding relies on the evidence that the period distribution of first overtone RR Lyrae (RRc) presents a secondary peak located at $P \approx$ 0.281 days. In the following we will call this peak as the *Macho peak*.

On the other hand, current nonlinear, convective models (Bono et al. 1997) suggest that such a peak might be the signature of a more metal-rich population of RR Lyrae stars. A similar feature in the period distribution of RRc stars was also detected by Kaluzny et al. (1995) in the Sculptor dwarf spheroidal (dSph) galaxy. The *macho peak* in this sample was located at $P \approx$ 0.290 days. According to theoretical and empirical evidence, fundamental RR Lyrae (RRab) present an anti-correlation between period and amplitude, i.e. RRab stars with longer periods present smaller luminosity amplitudes. On the other hand, RRc stars present, in the Bailey diagram (luminosity amplitude vs period), a distribution that resembles a "bell" shape (Bono et al. 1999). The Bailey diagram of RRc variables in Sculptor shows two shifted "bell" shapes, and the bulk of stars are located across the two peaks detected in the period distribution.

Theoretical and empirical findings also bring forward that the distribution of RRab stars in the Bailey diagram is marginally affected by metal content for $[Fe/H] \leq -0.6$. Oddly enough, current theoretical predictions do suggest that an increase in the metal abundance causes, at fixed input parameters, a decrease in the mean luminosity and, in turn, a decrease in the pulsation period of RRc stars. The aftermath of this change is that two RRc samples characterized by two different mean metallicities disclose two different "bell" shapes in the Bailey diagram. Therefore the occurrence of a broad distribution in the Bailey diagram and in the period distribution of RRc stars might be the fingerprint that the underlying stellar population presents a large spread in metallicity. RR Lyrae variables in Sculptor appear as the template for this effect, since current spectroscopic measurements support the evidence that its mean metal content is $\langle [Fe/H] \rangle \simeq -1.5$ dex with a dispersion of $\sim \pm 0.9$ dex (Tolstoy et al. 2002). The same outcome applies for RR Lyrae in LMC, since spectroscopic measurements of 15 field RR Lyrae stars indicate a $\langle [Fe/H] \rangle = -1.7$ with tails extending to -0.8 and to -2.4 (Alcock et al. 1996). To investigate in more detail whether this finding is an intrinsic feature of RR Lyrae in these two stellar systems, we decided to investigate the pulsation properties of RR Lyrae in Local Group (LG) dwarf galaxies, since they present a broad dispersion in chemical composition.

2. Galactic and Local Group stellar systems

A glance at the period distribution of RR Lyrae in two populated Galactic globular clusters (GGCs), M3 and M15, i.e. the prototypes of Oosterhoff type I (Oo I) and Oosterhoff type II (Oo II) groups[1], discloses that no firm conclusion can be drawn due to the limited number of RRc variables. The only exception to this rule is ω Cen. This is a massive globular cluster (total luminosity $M_V = -10.29$ mag; Harris 1996) and presents a well-defined metallicity spread (Rey et al. 2000; Pancino et al. 2002). Even though the census of RR Lyrae stars in this cluster is far from being complete, the period distribution of RR Lyrae stars collected by Kaluzny et al. (1997) seems to show the *Macho peak*. The problem of limited samples in individual GGCs might be overcome by taking into account the cumulative period distribution of RR Lyrae stars in GGCs (Clement et al. 2001). Both Oo I and Oo II GGCs show the *Macho peak* (see their Fig. 3). Interestingly enough, this secondary feature is more evident among Oo II clusters which present a larger spread in metal abundance, namely $-2.29 \leq [Fe/H] \leq -0.28$.

Now, we move our analysis to LG dwarf galaxies. The reasons are manifold: *i)* a large fraction of them hosts sizable samples of RR Lyrae stars (Mateo 1998); *ii)* the dynamical and star formation history of these stellar systems are substantially different than GGCs, and therefore they supply the unique opportunity to investigate whether these properties affects the pulsation properties of RR Lyrae; *iii)* recent results based on the radial distribution of RR Lyrae stars in the Galactic halo (Vivas et al. 2001, see also the paper by Vivas at these proceedings) strongly support the evidence that the clump of stars detected by the Sloan Digital Sky Survey (Yanny et al. 2000), at approximately 50 kpc from the Galactic center, might be the tidal stream left over by the Sagittarius (Sgr) dSph.

This means that pulsation properties of RR Lyrae stars in the halo clump can be soundly adopted to single out whether they do belong to the Galactic halo or to Sagittarius. Data plotted in Fig. 1 clearly show that the period distribution of RRc

[1] According to Oosterhoff (1939, 1944) GGCs that host RRab variables with a mean period ≈ 0.55 days are called type I, while those with a mean period ≈ 0.65 days are called type II clusters.

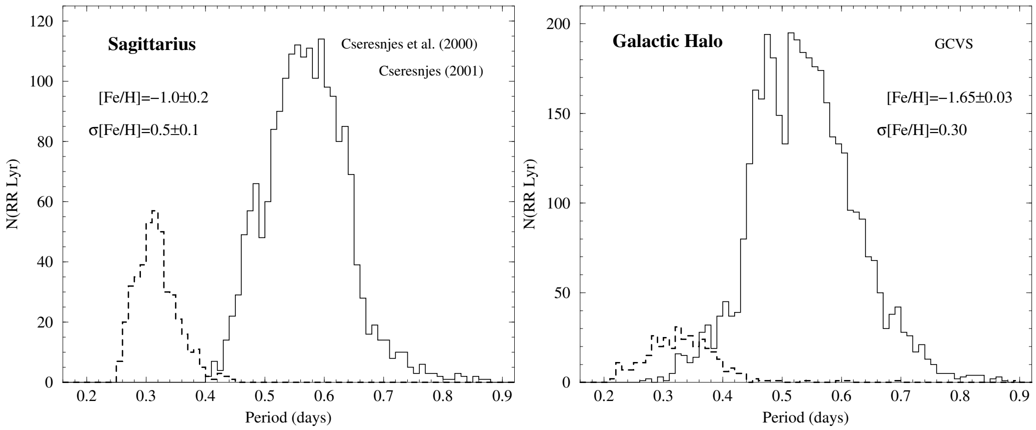

Fig. 1. Period distribution of RR Lyrae stars in the Sgr dSph (Cseresnjes, Alard, & Guibert 2000; Cseresnjes 2001) (*left*) and in the Galactic halo, (General Catalogue of Variable Stars, GCVS; *right*).

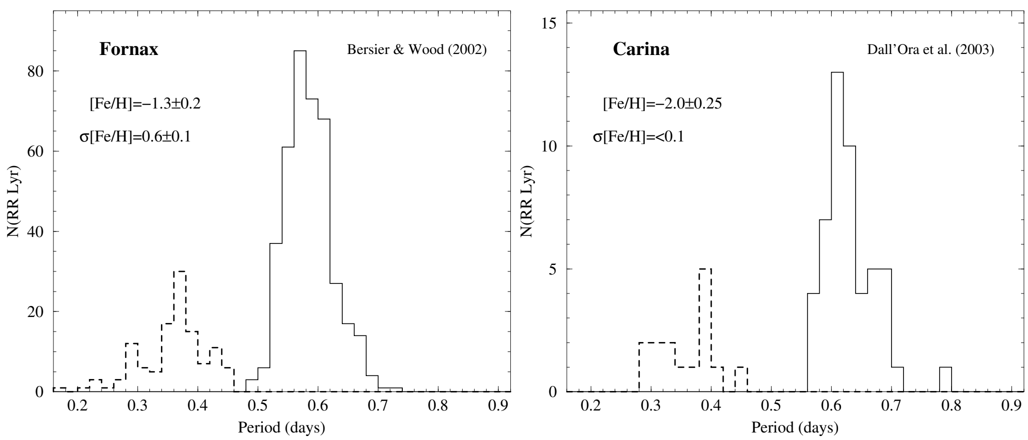

Fig. 2. Period distribution of RR Lyrae in Fornax (Bersier & Wood 2002) (*left*) and in Carina (Dall'Ora et al. 2003) (*right*) dSph galaxies.

in Sagittarius presents a well-defined peak centered on $P \approx 0.32$ days. On the other hand, data available in the literature indicate that RRc in the halo present a broad period distribution ranging from 0.2 to 0.4 days and do not show a well defined peak. Oddly enough, the spread in metallicity of RRc stars in the halo is narrower ($\langle [Fe/H] \rangle \simeq -1.65$ dex with a dispersion of $\sim \pm 0.3$ dex; Suntzeff, Kinman, and Kraft 1991) than in Sagittarius ($\langle [Fe/H] \rangle \simeq -1.0$ dex with a dispersion of $\sim \pm 0.8$ dex; Tolstoy et al. 2002). Unfortunately, we still lack detailed information concerning the period distribution and the luminosity amplitude of RRc stars in the new clump, and therefore we cannot perform a detailed comparison with quoted samples.

Moreover, both the mean and the spread in chemical composition in dwarf spheroidals are widely debated, since the difference between spectroscopic measurements and photometric indexes is larger than current uncertainties (Tolstoy et al. 2001). At

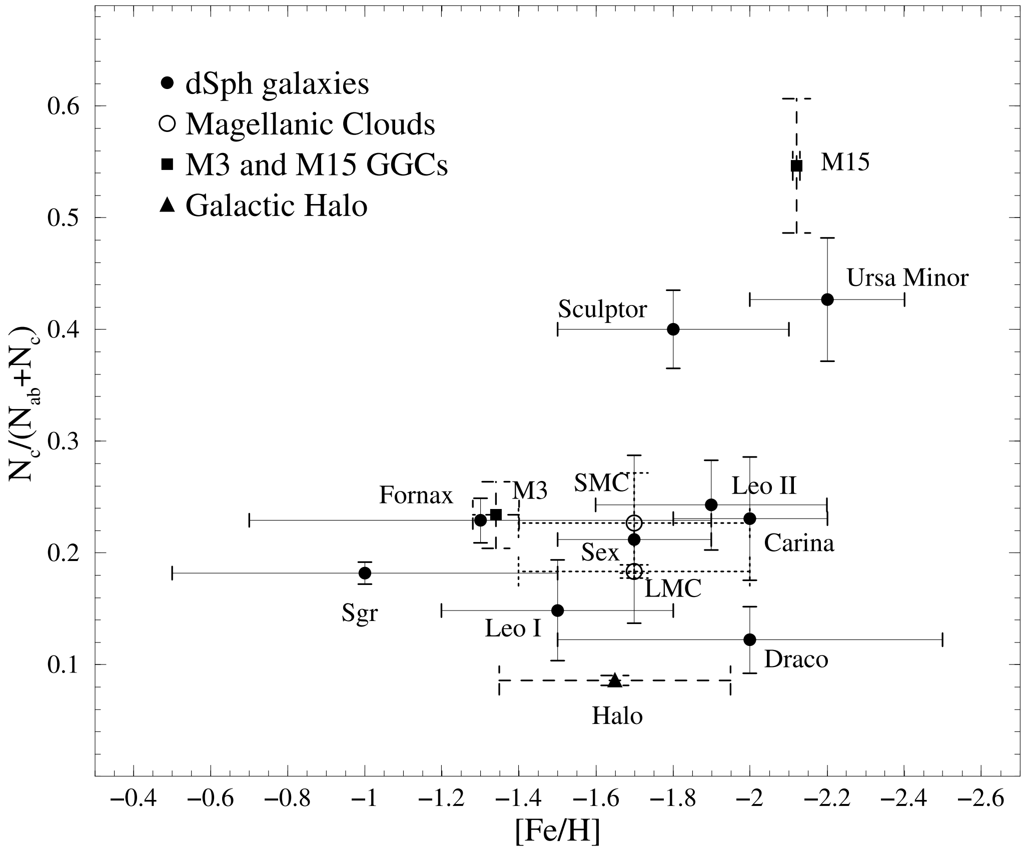

Fig. 3. Relative number of first-overtones (RRc) to the total number of RR Lyrae for the labeled stellar systems. Data were collected by: Dall'Ora et al. (2003) (Carina); Nemec (1985) (Draco); Held et al. (2001) (Leo I); Siegel & Majewski (2000) (Leo II); Kaluzny et al. (1995) (Sculptor); Mateo, Fischer, & Krzeminski (1995) (Sextans); Nemec, Wehlau, & Oliveira (1988) (Ursa Minor); Cseresnjes (2001) (Sagittarius); Bersier & Wood (2002) (Fornax); Alcock et al. (1996) (LMC); Graham (1975), Smith et al. (1992) (SMC); GCVS (halo); Corwin, & Carney (2001) (M3); Silbermann & Smith (1995) (M15). Metallicity spreads are from Mateo (1998).

present, it is not clear whether such a discrepancy is caused by a different evolution either of Iron-peak elements or of α-elements such as Calcium. Finally, we note that the large spread in CaII triplet metal abundances might also be due to a systematic difference among intrinsic stellar parameters such as gravity and temperature (Erdelyi-Mendes & Barbuy 1991). This not withstanding, preliminary results by Vivas et al. (2001) suggest a mean period of RRab stars in the clump of $\langle P \rangle = 0.58$ days. Interestingly enough, this value is very much similar to the mean period of RRab in Sgr, $\langle P \rangle = 0.57$ days (Cseresnjes 2001), than to RRab in the Galactic halo, i.e. $\langle P \rangle = 0.54$ days (General Catalogue of Variable Stars, GCVS). This finding is further strengthened by the fact that recent data collected by Cseresnjes (2001) for RR Lyrae stars toward Sagittarius (Galactic Center, namely a mix of thick disk and bulge stars), present a mean period of RRab variables similar to the Galactic halo, i.e. $\langle P \rangle = 0.55$ days.

Data plotted in Fig. 2, together with data collected by Cseresnjes (2001) (see his Figure 5) suggest a tight connection between the occurrence of the *Macho peak* in the period distribution of RRc stars and a large spread in metal content. The only exception to this rule seems to be the Sgr dSph. Whether this evidence could cast some doubts on the observed spread in metallicity, it is not clear yet. Note that for several LG dwarfs the sample of RRc stars is too small (Carina) or the entire sample is not complete (Draco, Sextans).

To investigate in more detail the problem we decided to adopt a new observable, namely the ratio between RRc stars and the total number of RR Lyrae. Figure 3 shows this ratio as a function of the metal content for stellar systems in the Galaxy and in the LG. Data plotted in this figure show a substantial difference between the relative number of RRc stars in Sgr and in the halo. Although, RRc in the halo might be affected by a selection bias, this parameter seems quite promising to split RR Lyrae stars belonging to different parent populations.

3. Conclusions

The *Macho peak* in the period distribution of RRc variables appears to be connected with a large spread in the metal content of the parent population. This finding is supported by RR Lyrae in GGCs (ω Cen, Oo II clusters) and in LG dwarf galaxies. The only exception to this empirical evidence are RR Lyrae in Sagittarius. We found that the mean period of RRab variables in the halo clump detected by Vivas et al. (2001) agrees quite well with the mean period of RRab in Sagittarius. Finally, we found that the ratio between RRc and total number of RR Lyrae seems a robust observable to figure out whether RR Lyrae in the halo clump do belong to Sagittarius or to the Galactic halo.

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